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(71) Applicant (*for all designated States except US*): **HB INNOVATION LTD.** [CA/CA]; Suite 300, 2085 Hurontario Street, Mississauga, Ontario L5A 4G1 (CA).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **HARRISEN, Howard, R.** [CA/CA]; 1302 Hartley Drive, Mississauga, Ontario L5H 1N9 (CA). **BROWN, Jeffrey, R.** [CA/CA]; 574 Durie Street, Toronto, Ontario M6S 3H1 (CA).

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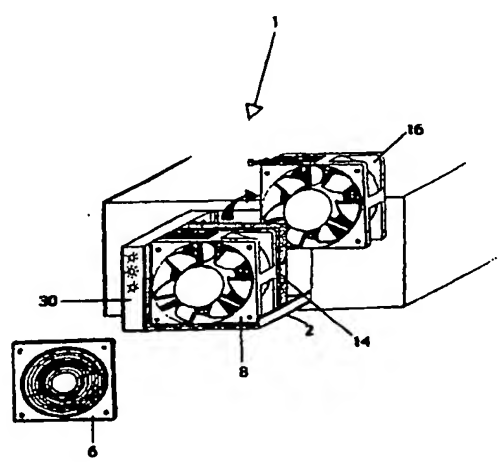
(54) Title: COMPACT DUAL REDUNDANT COOLING FANS



(57) Abstract: A compact dual redundant cooling fan assembly has an outboard cooling fan, a turbulent to laminar flow modification element, and an inboard cooling fan mounted in a series configuration. A connecting sleeve directs the combined output into a cabinet containing components to be cooled. A sliding drawer within the connecting sleeve detachably holds said outboard cooling fan, said flow modification element, and said inboard cooling fan, allowing for the hot swappable replacement of defective components. A controller is in communication with a power source, said outboard fan, said inboard fan, and at least one sensor monitoring the status of each of said outboard cooling fan and said inboard cooling fan. Said controller is configured to maintain said combined output above a minimum control level at all times, regardless of the failure of said outboard fan or said inboard fan.

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B. FIELDS SEARCHED

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 101 459 A (VINSON WADE D ET AL) 8 August 2000 (2000-08-08) column 6, line 16 - line 50; figure 2 ---	1-54
A	US 5 572 403 A (MILLS R STEVEN) 5 November 1996 (1996-11-05) column 8, line 24 - line 67; figure 4 ---	1-54
A	EP 0 588 414 A (IBM) 23 March 1994 (1994-03-23) column 3, line 39 -column 4, line 5; figure 1 ---	1-54
A	DE 25 03 623 A (SIEMENS AG) 5 August 1976 (1976-08-05) page 3, paragraph 4; figure 1 ----	1-54

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Rubenowitz, A

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Patent document cited in search report		Publication date	Patent family member(s)	Publication date
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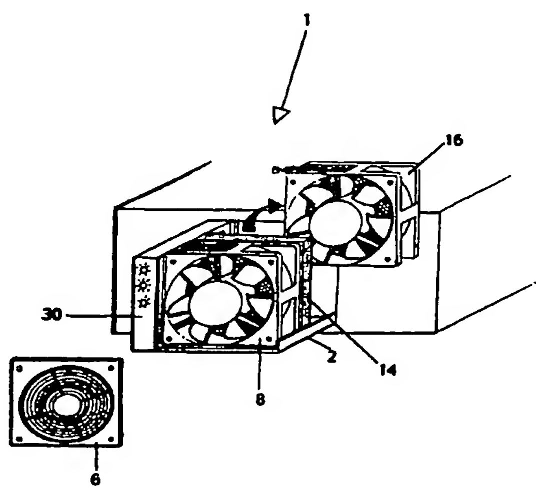

(57) **Abstract:** A compact dual redundant cooling fan assembly has an outboard cooling fan, a turbulent to laminar flow modification element, and an inboard cooling fan mounted in a series configuration. A connecting sleeve directs the combined output into a cabinet containing components to be cooled. A sliding drawer within the connecting sleeve detachably holds said outboard cooling fan, said flow modification element, and said inboard cooling fan, allowing for the hot swappable replacement of defective components. A controller is in communication with a power source, said outboard fan, said inboard fan, and at least one sensor monitoring the status of each of said outboard cooling fan and said inboard cooling fan. Said controller is configured to maintain said combined output above a minimum control level at all times, regardless of the failure of said outboard fan or said inboard fan.

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Compact Dual Redundant Cooling Fans

Field of the Invention

This invention relates to a unique series configuration of redundant cooling fans intended for cooling components within an enclosed cabinet. The configuration is modular, extremely compact, uses readily available low cost axial fans, provides constant cooling by allowing for automatic fail over between the fans, and requires no special baffling within the cabinet. A user display panel identifies the failed fan which may then be replaced (or "hot swapped") without shutting down the system.

Acknowledgement of Prior Art

The need for highly reliable, fault tolerant, and hot swappable cooling has increased as the mission critical use of high performance electronics becomes more and more prevalent. In many cases a loss of cooling for more than a brief moment would damage these electronic components.

This has driven a tremendous amount of inventive activity in the field as evidenced by numerous recent patents including US patent 6,247,898 issued 6/19, 2001 to Henderson, et al (assigned to Micron Electronics), US Patent 6,108,203 issued 8/22, 2000 to Dittus, et al (assigned to IBM), US patent 6,101,459 issued 8/8, 2000 to Tavallaei, et al (assigned to Compaq Computer), US patent 6,061,237 issued 5/9, 2000 to Sands, et al (assigned to Dell Computer), US patent 6,040,987 issued 3/21, 2000 to Schmitt, et al (assigned to Dell), US patent 6,031,717 issued 2/29, 2000 to Baddour, et al (assigned to Dell Computer), US patent 6,021,042 issued 2/1. 2000 to Anderson, et al (assigned to Intel Corporation), US patent 6,005,770 issued 12/21, 1999 to Schmitt

(assigned to Dell Computer), US patent 5,572,403 issued 11/5, 1996 to Mills, et al (assigned to Dell Computer), and US patent 5,562,410 issued 10/8, 1996 to Sachs, et al (assigned to EMC Corporation),

Most of these patents, including US Patent 6,108,203 assigned to IBM, US patent 6,101,459 assigned to Compaq, US patent 6,061,237 assigned to Dell, US patent 6,031,717 assigned to Dell, US 6,021,042 assigned to Intel, and US patent 6,005,770 assigned to Dell teach redundant fans operating in parallel. Of these, US 6,108,203, US 6,061, 237, US 6,031,717, US 6,021,042, and US 6,005,770 all teach various types of baffling to present the reverse flow of air through the defective fan, and the ensuing loss of cooling air pressure within the cabinet. US 6,101,459 teaches that this reverse flow of air may be prevented by placing a second, back-up, fan in series with each of the parallel fans. However it must be noted that this same patent also teaches that the back-up fans remain idle until required. These patents also suggest various ways to ease the process of replacing the defective fan(s). US 6,061, 237 teaches that two parallel fans may be placed at an angle to save space.

Only two of these patents, US 6,101,459 assigned to Compaq and US 5,572,403 assigned to Dell, suggest a series configuration for the cooling fans. Of these, US 6,101,459 teaches that the second fan in the series is for back-up purposes only, and will remain idle until required as previously noted. US 5,572, 403 does teach that the series configured fans run simultaneously, in counter-rotating fashion, and further teaches that a plenum bypass be used to reduce impedance and increase airflow in the event of a fan failure. However this approach requires specialized fans and also requires further baffling within the cabinet to accommodate the plenum bypass flow when required.

An additional two of these patents, US 6,040,981 assigned to Dell and US 5,562,410 assigned to EMC address the issues of easy fan removal and hot swappable fans. US 6,040,981 teaches a removable fan with camming handle that aligns the fan and re-connects power in a single operation. US 5,562,410 teaches a self aligning hot-pluggable fan assembly, primarily to complement the fault tolerant characteristic of RAID based disk arrays.

Finally, US 6,247,898 teaches a method of controlling the speed of a plurality of fans connected in parallel fashion.

Summary of the invention

As taught by prior art, a currently accepted solution is to install dual fans (or blowers) in a parallel configuration such that one fan has the capacity to cool the entire cabinet, at least on a minimal cooling basis. In this manner, the failure of one fan can be tolerated without damaging the equipment. While this approach works, the parallel installation has the following associated problems; (1) mounting two fans side by side requires twice as much cabinet space, (2) the fail over mechanism must contain sufficient baffling to prevent air from escaping (or entering) through the defective fan, a complex and bulky approach, (3) further baffling is required to ensure that the air stream is directed consistently regardless of which fan is operating, and (4) the system may need to be shut down before replacing the defective fan.

Intuitively it makes more sense to mount the fans in series rather than in parallel – i.e. place one fan behind the other rather than one fan beside the other. However the problem with this approach has been that two fans in series do not perform well because the exit conditions from the first fan (turbulent flow) do not match the ideal entry conditions (laminar flow) for the second fan.

Despite this drawback, the series configuration solves many of the problems associated with the parallel configuration; (1) a series configuration takes less cabinet space than a parallel configuration, (2) no baffling is required to prevent air from escaping through the defective fan – in fact air must flow through the defective fan in order for the series configuration to work, (3) no further baffling is required to ensure that the air is consistently directed since the two fans are mounted on the same axis, and (4) because of the total absence of this baffling, a defective fan may be safely replaced without shutting down the system.

Therefore the present invention discloses a method of resolving the turbulent / laminar flow issue associated with the series configuration so that the above benefits can be realized. Further, the present invention discloses several additional features that will

contribute to ease of use, ease of maintenance, and lower cost such as; (1) an integrated filter / flow control element, (2) a user interface panel to show the status of both fans and the integrated filter element, (3) the ability to replace the filter element or the defective fan from outside the cabinet while the system is running, and (4) a very compact and modular format that takes up marginally more cabinet space than a single fan system.

It is commonly known that an axial fan works best if it sees laminar rather than turbulent flow on the input side. This condition is met with a single fan since there is nothing on the input side to generate a turbulent flow. However this is not the case with a series configuration since the output of the first fan (as in the case of all fans) is unfortunately a turbulent flow.

The present invention discloses that this problem can be resolved by placing a filter element / diffuser between the two fans. The primary purpose of most filters is to remove unwanted particulates from the air. However a very useful secondary impact of the filter, for this application, is to convert a turbulent flow to a laminar flow. Therefore the result of placing the filter between the two fans is to convert the input seen by the inboard fan to a laminar flow, thereby increasing its efficiency to a level approaching that of the outboard fan.

The use of an intermediate filter element / diffuser will not affect one of the primary inherent advantages of a series fan configuration – the air flow will always be in the same direction, even during a fan failure, and no baffling changes will be required within the cabinet. In the event of an outboard fan failure, the inboard fan will continue to draw air through the filter element / diffuser and "push" it in the *same* direction. Air will also continue to flow in the *same* direction if the inboard fan fails, except that the air will be "pushed" rather than "pulled" through the filter element / diffuser.

Although the *direction* of airflow will remain consistent in a series fan configuration with a single fan failure, the *volume* of airflow will be reduced if the remaining fan continues to operate at the same speed. This is an acceptable situation only if the volume of airflow does not fall below the minimum required to dissipate the heat generated in the cabinet being cooled. The present invention teaches that a control system may be required to

sense the fan failure and adjust the remaining fan speed accordingly in order to ensure that this minimum requirement is met until the defective fan can be replaced. This type of control may be easily implemented since (1) many fans today are available with fault sensors to indicate an impending failure / total failure and (2) fan speed can be easily controlled by controlling the input parameters such as voltage.

Should a fan fail, the present invention teaches that it may be replaced without having to shut down the system being cooled. This is made possible by the fact that the compact redundant cooling fans fit within a "sliding drawer" that can be pulled away from the cabinet without interrupting the airflow. The defective fan may be replaced while the drawer is in the "out" position, and then the drawer may be returned to the "in" position without affecting system operation or necessitating a system shut down. The control system will detect the new fan, and adjust speeds accordingly. Note that the filter element may also be replaced while the drawer is in the "out" position, again without affecting system operation.

Further, the present invention teaches several methods of increasing the efficiency of the series fan configuration by minimizing the impedance of the filter element / diffuser under normal operation, and the possible combined filter element / diffuser and stalled fan blade impedance in the event of a fan failure. A unique offset series configuration incorporates a supplementary air inlet or air outlet which may be opened in the event of a fan failure to improve the single fan efficiency while maintaining a consistent direction and rate of flow.

Finally the present invention teaches that the entire compact redundant cooling fan assembly may be configured as a self contained module that may be easily added to virtually any system without further modifications to the system cabinet. Further, multiple redundant cooling fan assemblies may be added to a single cabinet for greater capacity and / or to provide multiple fail-safe airflows. This modular aspect of the invention will greatly simplify the task of thermal management for system designers.

Embodiments

Embodiments of the invention are described by way of example with reference to the drawings in which:

Figure 1 illustrates an inefficient series fan configuration,
Figure 2 illustrates an efficient series fan configuration with diffuser elements,
Figure 3 provides an overview of the compact redundant cooling fan configuration,
Figure 4 provides a side view of the compact redundant cooling fan configuration,
Figure 5 provides a side view of the compact redundant cooling fans in normal operation,
Figure 6 provides a front view of the compact redundant cooling fans with a control panel, and
Figure 7 illustrates how the compact redundant cooling fan drawer may be withdrawn from a cabinet,
Figure 8 details the replacement of one of the compact redundant cooling fans,
Figure 9 shows how two compact redundant cooling fan assemblies may be mounted in parallel,
Figure 10 shows a compact redundant cooling fan module with a supplementary air inlet and outlet,
Figure 11 provides a connection diagram for the compact redundant cooling fan controller, and,
Figure 12 illustrates a control algorithm for the compact redundant cooling fan controller in flow chart format.

FIG. 1 illustrates an inefficient series fan configuration comprised of three independent axial cooling fans mounted such that the output from one fan becomes the input to the next fan in the series. In this case the output from outboard fan 8 becomes the input to inboard fan 16, and in like manner the output from inboard fan 16 becomes the input to second inboard fan 17. Basic series fan configurations may be comprised of two or more axial fans configured in this manner.

An axial fan works best if it sees laminar rather than turbulent flow on the input side. This condition is met with a single fan since there is nothing on the input side to generate a

turbulent flow. However this is not the case with a basic series configuration since the outputs of the outboard fan 8 and inboard fan 16 (as with all axial fans) are unfortunately turbulent flows as depicted by turbulent air flow 10 and second turbulent air flow 11. Therefore a basic series configuration is inefficient because all inboard fans will see a turbulent flow on the input side.

In contrast, FIG. 2 illustrates an *efficient* series fan configuration due to the insertion of filter element / diffuser 14 and second filter element / diffuser 15 between the fans.

The primary purpose of most filters is to remove unwanted particulates from the air. However a very useful secondary impact of the filter, for this application, is to convert a turbulent flow to a laminar flow. Therefore the result of inserting filter element / diffuser 14 between outboard fan 8 and inboard fan 16 is to convert the input seen by the inboard fan 16 to a laminar air flow 12, thereby increasing the efficiency of inboard fan 16 to a level approaching that of outboard fan 8. Likewise, the second filter element 15 will convert the input seen by second inboard fan 17 to a second laminar flow 13, thereby improving the efficiency of second inboard fan 17.

In certain applications the use of a filter between the two serially mounted axial fans may cause an unwanted restriction of flow. As an example, second filter element / diffuser 15 will need to act as a diffuser but it does not need to act as a filter since the first filter element / diffuser 14 will have already filtered the incoming air. In these cases the second filter / element diffuser 15a may simply be an efficient diffuser comprised, for example, of a number of vanes or tubes mounted in the path of the air and positioned to direct the air into second inboard fan with laminar flow characteristics. Further, the vanes or tubes may be configured to create a "swirl" of air that would more easily flow past the stationary fan blades of a defective fan, therefore minimizing any impedance caused by the defective fan. While the number of different diffuser designs and their related efficiencies is vast, the principle of converting the airflow from turbulent to laminar as it applies to this invention remains the same.

FIG. 2 also illustrates the impact of a fan failure. If the outboard fan 8 fails, then the inboard fan 16 and second inboard fan 17 will continue to draw air through the assembly and "push" it in the same direction, i.e. combined air flow 22 will continue and no

external baffling changes will be required to keep it flowing in the same direction. A similar result will occur if inboard fan 16 or second inboard fan 17 fails. This ability to continue to provide a flow of air in the same direction despite the loss of a fan is the primary inherent advantage of a series fan configuration.

In the event of an outboard fan 8 failure, the fan blades may continue to rotate or they may remain fixed or "locked". However in the case of an outboard fan 8a with variable pitch fan blades, outboard fan blade 9 will remain in an oblique position during normal operation (i.e. while rotating in the direction defined by arrow 7) and then return to position 9a in the event of a failure. Since position 9a aligns the fan blade with the air flow, it will present a far lower input impedance as seen by inboard fan 16, therefore contributing to increased efficiency during an outboard fan 8a failure relative to an outboard fan 8 (i.e. fixed fan blade) failure. It follows that a variable pitch inboard fan 16 would also contribute to greater efficiency during the failure mode as it would present a lower output impedance as seen by outboard fan 8.

Although the *direction* of airflow will remain consistent in a series fan configuration with a single fan failure, the *volume* of airflow will be reduced if the remaining fan(s) continue to operate at the same speed. This is an acceptable situation only if the volume of airflow does not fall below the minimum required to dissipate the heat generated in the cabinet being cooled. In practice a control system may be required to sense the fan failure and adjust the remaining fan speed accordingly in order to ensure that this minimum requirement is met until the defective fan can be replaced. This type of control can be easily implemented since (1) many fans today are available with fault sensors to indicate an impending failure / total failure and (2) fan speed can be easily controlled by varying the input voltage.

During normal operation outboard fan 8, inboard fan 16, and second inboard fan 17 may all be operating at less than full rpm to produce the required combined airflow 22. The lower rpm will reduce the noise produced by each fan and also extend the life of the fan. Should the controller sense an impending or actual failure in one of these fans, then the voltage applied to the remaining two fans may be increased to the point where combined airflow 22 remains the same. The user may then be alerted to replace the defective fan.

A series configuration of "n +1" fans configured with intermediate filter elements / diffusers as described above will be tolerant to the failure of one fan where "n" is the total number of fans whose combined flow is required to meet the cooling requirements of the system or component(s) being cooled. FIG. 2 illustrates an example where "n" = 2, and "n + 1" = 3 fans in total. Actual configurations may include 2, 3 or more fans depending on cooling requirements. The remainder of this document will deal with dual redundant cooling fan configurations for reasons of simplicity, however it should always be noted that additional fans may be added to the serial configurations.

It is also possible that multiple compact redundant cooling fan assemblies may be mounted in parallel to meet cooling requirements. In this case, there is no need for the movable baffles normally associated with parallel configurations since each independent compact redundant cooling fan assembly is fault tolerant and will not allow the back flow or "leakage" of air in the event of a fan failure. These configurations may be practical to meet very high air flow requirements, to produce independently directed air flow streams, or where space considerations limit the number of fans that may be mounted in a serial fashion.

Should a fan fail, the next requirement is to replace the defective fan without having to shut down the entire system. This is made possible by the fact that the compact redundant cooling fans fit in a sliding "drawer" that can be pulled away from the cabinet without interrupting the air flow as illustrated in FIG. 3. In this case inboard fan 16 is being replaced while sliding drawer 2 is in the "out" position. Sliding drawer 2 may then be returned to the "in" position without affecting system operation or necessitating a system shut down. The control system will detect the presence of a new and fully functional inboard fan 16, adjust the speeds of both outboard fan 8 and inboard fan 16 accordingly, and reset the lights on control panel 30 to reflect normal operation. Note that the filter element / diffuser 14 could also be replaced while the sliding drawer 2 is in the "out" position, again without affecting system operation. Finger guard 6 has been added to the configuration for safety reasons.

Figure 4 provides further detail in a side view of compact dual redundant cooling fan 1. Outboard fan 8 and inboard fan 16 are serially mounted in sliding drawer 2 such that the air flowing from outboard fan 8 flows directly into inboard fan 16. Sliding drawer 2 slides

into and out of internal sleeve 3 as depicted by drawer movement arrow 18. Sliding drawer 2 requires a minimum opening in cabinet 4, therefore making it easier to maintain the integrity of the EMI shield.

Internal sleeve 3 has at least four distinct functions; (1) to provide a means to mount compact dual redundant cooling fan 1 on cabinet 4, (2) to provide a means to allow sliding drawer 2 to slide "in" or "out", (3) to support sliding drawer 2 whilst in the "in" or "out" position, and (4) to provide baffling such that combined air flow 22 *only* exits the assembly through the open end of internal sleeve 3.

Flange 21 may be used to secure internal sleeve 3 to cabinet 4 with machine screws or some other suitable means. Latch 19 may be used to hold and seal tab 20 against flange 21, i.e. to hold sliding drawer 2 "in", until released. Back lip 5 extends outward from the normal geometry of sliding drawer 2 to prevent the accidental removal of sliding drawer 2 by coming to rest against an extended portion of flange 21 when sliding drawer 2 is in the full "out" position. A means may be provided to completely remove sliding drawer 2 from internal sleeve 3 when and if required.

The output from outboard fan 8 is in fact turbulent airflow 10. This is an inherent characteristic of this type of fan, and unfortunately one that renders a direct series *configuration inefficient. Compact redundant cooling fan 1 utilizes filter element / diffuser* 14 for two distinct purposes (1) to filter unwanted particulate from the air and (2) convert turbulent airflow 10 to laminar air flow 12. Filter element 14 should be selected to optimize both functions such that a reasonable laminar airflow 12 can be achieved before the air enters inboard fan 16.

Alternatively, an air filter optimized for removing particulates may be mounted between finger guard 6 and outboard fan 8, leaving the filter element 14 to be fully optimized for turbulent to laminar air flow conversion. Under this configuration filter element / diffuser14 may become a screen, a laminar flow element consisting of a number of tubes mounted co-axially with the fans, a series of flow directing vanes, or some combination thereof. Further, the laminar flow element may be made more effective by fashioning an air funnel at the entry point to each tube with the funnel opening directed / skewed towards the source of the air as it comes off the blades of outboard fan 8. Regardless of

configuration, the flow related objective of filter element / diffuser 14 is to complete the conversion from turbulent to laminar flows while introducing a minimum amount of back pressure as seen by outboard fan 8, thereby contributing to the overall efficiency of the compact dual redundant cooling fan 1.

Outboard fan 8 and inboard fan 16 may rotate in the *same or different directions*. This aspect of the configuration will be somewhat dependent on the cost and performance objectives associated with a given application. Also, any efficiency gained by having counter-rotating fans should be weighed against the service cost of stocking two types of spares.

FIG. 5 shows the compact dual redundant fan 1 in operation. In this case sliding drawer 2 has been moved "in" such that finger guard 6 is flush with the outside of cabinet 4. Sliding drawer 2 slides within the internal sleeve with sliding interfaces at flange 21 and back lip 5. Alternatively, sliding drawer 2 may be configured to slide on rails or some other suitable means.

Sliding drawer 2 is prevented from moving farther into cabinet 4 by tab 20 (top and bottom) when it interfaces with the outer edge of flange 21.Sliding drawer 2 is then held in place by latch 19. In some cases an aesthetic cover may be configured to snap onto the outside of sliding drawer 2, once in place, to improve the appearance of the cooling module. Further, the aesthetic cover would provide visual access to the control panel so that the operation of compact dual redundant fan 1 could still be easily monitored.

As in FIG. 4, cooling air flows efficiently through outboard fan 8, filter element / diffuser 14, and inboard fan 16 to form combined air flow 22.

The direction of combined air flow 22 remains consistent whether one or both of outboard fan 8 and inboard fan 16 is / are operational. This precludes the requirement for any incremental baffling to ensure that the direction of combined airflow 22 remains consistent in the event of a fan failure.

In the event of an outboard fan 8 failure, combined Air Flow 22 will continue to flow *into* outboard fan 8 and *into* cabinet 4 – i.e. no airflow will be lost *out* through outboard fan 8.

Likewise in the event of an inboard fan 16 failure, combined air flow 22 will continue to flow *into* inboard fan 16 and *into* cabinet 4 – i.e. no air flow will be lost *out* through inboard fan 16. This precludes the requirement for any baffling to prevent the loss of any combined air flow 22 through the defective fan.

The last two paragraphs outline a very important characteristic of the series fan configuration – no baffling is required to accommodate a failed fan scenario. This contrasts sharply with the parallel fan configuration where substantial baffling is required to prevent the loss of air through the defective fan and to keep the direction of airflow consistent in the event of a fan failure. As a result compact dual redundant cooling fan 1 has a very small format, and it may be installed as a stand-alone cooling module that requires no further cabinet modifications.

Outboard fan 8 may need to be rated at a higher capacity than inboard fan 16 to compensate for the added backpressure introduced by filter element / diffuser 14 and inboard fan 16, if and when inboard fan 16 is defective and / or stationary. Conversely stated, inboard fan 16 may be rated at a lower capacity than outboard fan 8 because it will not "see" the same incremental causes of backpressure. In practice both fans may be of the same rating, but should they be so configured that the ratings match the higher rating required by outboard fan 8. This will ensure that Combined Air Flow 22 will always exceed the minimum required regardless of whether one or both fans is / are in operation.

During normal operation the effect of filter element / diffuser 14 is to allow both fans to run efficiently and simultaneously. Therefore, under normal circumstances, outboard fan 8 and inboard fan 16 may be left running at less than full rpm as long as combined airflow 22 meets the cooling requirements. The response to a fan failure will be immediate since the secondary fan is always running, albeit at a lower rpm. In other words the response time for the secondary fan to ramp up from partial to full rpm is much faster than the time to go from stopped to full rpm. The latter situation occurs in current serial fan configurations where the back-up fan does not run until needed.

It can be deduced from FIG. 5 that the size of the opening in cabinet 4 will be only slightly larger than the size of outboard Fan 8. In a parallel configuration the opening

would be approximately twice this size since the two fans would be mounted side-by-side. The volume of space required in Cabinet 4 will be much smaller than a parallel configuration since no extra internal baffling is required. This 2:1 reduction in the size of the opening combined with the much smaller internal volume requirement represents the true benefit of the series configuration from a system designer's perspective.

In a simple configuration compact dual redundant cooling fan 1 may be implemented without a controller by using two fans, each of which is capable of providing the full combined air flow 22 required to cool the thermal load. Under normal operating conditions the combined airflow produced by the fans will actually exceed the minimum requirement, keeping the load cooler than necessary. A fan failure can be tolerated since the remaining fan will already be running, and is capable of carrying the load. As described above, no further baffling is required since the fans are in series. A simple indicator light will,flag the operator to replace the defective fan.

In other configurations a controller may be required as shown in FIG. 6, which presents a front view of the compact dual redundant cooling fan 1. In this drawing the full extent of tab 20 may be seen around the perimeter of the unit, and the front face of finger guard 6 may be seen in the central portion of the unit. Control panel 30 contains indicator lights 32 for outboard fan 8, inboard fan 16, and filter element / diffuser 14 (please see FIG. 5).

An aesthetic cover may be affixed over the entire front face of compact dual redundant cooling fan 1 providing that airflow is not impeded to the degree that it will affect cooling performance. In most cases indicator lights 32 will need to be visible through the aesthetic cover so that the operator can respond to a fan problem, however this may not be an absolute requirement in situations where the operator may be initially alerted through some other means, for example through software. In the latter case the operator, once alerted to the problem, could remove the aesthetic cover and visually inspect indicator lights 32 to determine which fan is defective.

Fans are readily available with sensors for failure, or degradation in performance that might indicate imminent failure. This information can be used to inform the controller to increase the speed of the other fan in order to maintain a constant CFM output. The controller can also use the same information to illuminate the appropriate indicator light

32, alerting the operator to take action. Indicator lights 32 may be activated in several different modes, e.g. steady, flashing, red yellow or green, to communicate certain information and the level of severity of the problem to the user.

Under normal operation each fan may be running at less than maximum rpm to extend life, reduce noise, and to allow for an immediate increase in speed should the other fan fail. It is possible that one fan may be left idle (i.e. not running) during normal operation, however in practice it may be better to leave both fans running to some extent in order to (1) continually ensure that they are both operational (2) minimize any "ramp up" time in the event of a failure and (3) reduce any unnecessary static loads or sources of backpressure during normal operation. Again, it is the presence of the filter element / diffuser 14 between the fans that allow them to both run efficiently (reference FIG. 5)

FIG. 7 illustrates how compact dual redundant cooling fan 1 may be withdrawn from cabinet 4. Note that finger guard 6 has been removed in this diagram for illustrative purposes only, and that this would not normally be the case when servicing the unit.

FIG. 8 provides a top view of compact dual redundant cooling fan 1 and illustrates the method of replacing a defective fan without shutting down the system. In this scenario inboard fan 16 is defective, and this information would have been conveyed to the user through indicator light 32.

The first step in replacing defective inboard fan 16 is to pull out sliding drawer 2 until it is fully extended as depicted by drawer extension arrow 42. At this point back lip 5 will rest against the internal edge of flange 21 to prevent further forward movement of sliding drawer 2. Internal indicator light 33 may be used as a secondary check to ensure that the correct (faulty) fan is being removed.

Once sliding drawer 2 is in this position, inboard fan 16 may be removed by sliding it sideways to the right and disconnecting internal power and control cable 44 from internal power and control receptacle 46. FIG. 8 shows inboard fan 16 partially removed with approximately 30% of its width already beyond the right side of sliding drawer 2. Note that inboard fan 16 is completely outside of and can slide clear of cabinet 4. It can be

seen that filter element 14 and outboard fan 8 could be similarly removed without interfering with cabinet 4.

Once inboard fan 16 has been removed, outboard fan 8 remains running, and may be running at a higher RPM as set by controller 40, so that combined air flow 22 remains above the minimum airflow required to cool the components contained within cabinet 4. Note that the direction of combined air flow 22 will not change, as it remains contained and directed by internal sleeve 3, precluding the need for any change in baffling when running with only one fan. It can be seen from FIG. 8 that filter element / diffuser 14 and outboard fan 8 may be similarly removed without affecting the direction of the combined airflow 22. All of these operations can be completed without shutting down the system contained in cabinet 4.

Referring back to the scenario at hand, a new inboard fan 16 may be set in place in sliding drawer 2, and the internal power and control cable 44 may be re-connected. Controller 40 will then recognize that inboard fan 16 has been replaced, and that it is operational, and will adjust the speed of outboard fan 8 and inboard fan 16 accordingly. Sliding drawer 2 can then be pushed back into cabinet 4 such that finger guard 6 and control panel 30 are flush with the outside of cabinet 4. Indicator lights 32 may then be monitored by the operator for further problems. Indicator lights 32 and controller 40 may also be interfaced with the system in Cabinet 4 to alert the operator through other means such as the system monitor.

Sliding drawer 2 may be configured to accommodate standard sized fans available from a variety of manufacturers, e.g. 90mm x 90mm or 120mm x 120mm. These fans are readily available in a variety of thicknesses that loosely correspond to a range of CFM ratings, i.e. the thicker fans generally have a higher CFM rating. It follows that sliding drawer 2 may be configured to accept the thickest fan in a particular size range, and that slimmer or lower capacity fans may be accommodated by installing the fan in conjunction with a "shim" ring that takes up the extra space and holds the fan securely in place. This approach allows a standard size sliding drawer 2 to accommodate a variety of fan capacities, and also provides a convenient upgrade path since the shims may be removed or replaced with thinner shims to allow the installation of higher capacity fans.

This approach can be used to provide additional cooling, when required, without replacing the entire cooling subsystem.
In some applications it may be necessary to provide a fixed baffle 48 inside cabinet 4 to ensure that re-directed combined air flow 49 is directed appropriately for the application. This fixed baffle 48 will need to interface with internal sleeve 3 to prevent air leakage, however it will remain fixed in the event of a fan failure.

FIG. 9 shows how two compact redundant cooling fan assemblies may be mounted in parallel for increased airflow. In this case parallel baffle 50 interfaces with top inner sleeve 3a and bottom inner sleeve 3b to contain the output from both compact dual redundant fan assemblies and produce total combined air flow 54. Sealing cap 52 may be positioned between the two parallel assemblies to improve the airflow and to prevent any leakage of air in this area.

It is important to note that even though this is a parallel fan configuration, it does not require any of the specialized baffling normally associated with this type of installation. This is because each one of the parallel compact dual redundant fan assemblies is independently fault tolerant, and prevents the back flow of air through the fan assembly in the event of a fan failure. In other words, each fan assemble will *always* contribute to total combined air flow 54, and will *never* allow a portion of combined air flow 54 to leak back out to the ambient air around cabinet 4.

The parallel configuration also provides more flexibility in the event of a fan failure. In this case the controller has the ability to speed up three additional fans, rather than just one in a non-parallel installation, to maintain a constant total combined airflow 54. It follows that parallel configurations containing more than two compact dual redundant cooling fan assemblies will have an even greater ability to respond to a fan failure.

FIG. 10 shows a compact redundant cooling fan module with a supplementary air inlet and outlet to improve airflow in the event of a fan failure.

Under normal operation, air inlet baffle 70 and air outlet baffle 72 will direct the output from outboard fan 8 through inboard fan 16 to form combined airflow 22 as previously

described. Combined airflow 22 is further directed through air funnel 74 which may have an opening size that approximates the opening size of the fans.

In the event of an outboard fan 8 failure, air inlet baffle 70 may be moved to position 70a to reduce the input impedance seen by, and therefore increase the flow of air into, inboard fan 16. Outlet baffle 72 will remain in place to ensure that no air leaks from the output side to the input side of inboard fan 16. Now, combined airflow 22 will be comprised solely of the output from inboard fan 16, part of which will flow through the defective outboard fan 8 and another part of which will flow through the open inlet baffle 70a. .

Conversely, in the event of an inboard fan 16 failure, air outlet baffle 72 may be moved to position 72a to reduce the output impedance seen by, and therefore increase the flow of air out of, outboard fan 8. In this case inlet baffle 70 will remain in place to ensure that no air leaks from the output side to the input side of outboard fan 8. Now, combined airflow 22 will be comprised solely of the output from outboard fan 8, part of which will flow through the defective inboard fan 16 and another part of which will flow through the open outlet baffle 72a.

Inlet baffle 70 and outlet baffle 72 may be configured to operate automatically based on pressure differentials, or to be controlled by controller 40 (reference FIG. 8). In the former case a higher relative pressure between outboard fan 8 and inboard fan 16 would cause outlet baffle 72 to move to position 72a, and a lower relative pressure between the same fans would cause inlet baffle 70 to over to position 70a. In the latter case controller 40 may be used to control the position of the baffles in response to a failing or defective fan. In all cases the action taken serves to relieve the pressure differential and improve the flow of air through the configuration. However the use of the controller provides greater flexibility and does allow for certain load sharing scenarios between the two fans that might cause temporary pressure differentials between the fans that might otherwise be interpreted as a defective fan situation.

It is important to note that air inlet baffle 70 and air outlet baffle 72 may be configured, in conjunction with air funnel 74 and controller 40 (reference FIG. 8), such that the direction and rate of combined air flow 22 will remain constant even in the event of a fan failure.

This precludes the requirement for any further baffle changes within cabinet 4 in the event of a fan failure, meaning that the configuration may still be supplied as a standalone module that provides fault tolerant cooling.

It is also important to note that the use of air inlet baffle 70 and air outlet baffle 72 still allows for the replacement of a defective fan or filter element / diffuser while the system is running. This is because air inlet baffle 70 and air outlet baffle 72 have been configured to not interfere with the normal removal and replacement of the fan and filter element / diffuser element while sliding drawer 2 is in the "out" position as previously described.

Outboard fan 8 and inboard fan 16 may both be mounted with axis parallel to combined airflow 22 as shown in FIG. 10. Alternatively, outboard fan 8 and inboard fan 16 may both be mounted at a slight angle to the desired combined air flow 22, and not necessarily in a coaxial fashion, in order to improve the smooth flow of air between outboard fan 8 and inboard fan 16. In this case inner sleeve 3 and air funnel may be adaptively re-configured to ensure that combined airflow 22 flows in the desired direction.

FIG. 11 provides a connection diagram for the compact redundant cooling fan controller 40. Controller 40 receives its primary input from cooled component(s) 62, upon which the output of compact dual redundant cooling fan 1, i.e. combined airflow 22, impinges. This primary input may be comprised of information such as the temperature of cooled component(s) 62 and the rate of flow of air around cooled component(s) 62, and the current and / or anticipated workload on cooled component(s) 62. Information regarding the anticipated workload on cooled component(s) 62 will allow controller 40 to proactively respond a corresponding change in heat dissipation requirements by changing the speed of outboard fan 8 and / or inboard fan 16.

Controller 40 may also receive input from airflow sensor 60. Airflow sensor 60 provides information regarding the rate of combined airflow 22, and this information may be used by controller 40 to test for appropriate responses to changes in input to outboard fan 8 and / or inboard fan 16. A non-appropriate response to such an input may be used by controller 40 to determine that there may be a fault with filter element / diffuser 14 or one

of the fans. For example, controller 40 may determine that combined airflow 22 cannot be maintained above a threshold level and may deduce that (1) this problem may be caused by a seriously clogged filter element / diffuser 14 or in the worst case that (2) both fans may have failed or are failing simultaneously. The user would be alerted to take immediate action in either case, and a graceful shutdown procedure could be initiated if either situation persists for an unacceptable period of time.

Controller 40 may also receive input from position sensors 64, which inform controller 40 regarding the correct installed position of outboard fan 8, filter element / diffuser 14, and inboard fan 16. In the case of the fans, this information may be combined with input from combined control and monitor wires 66 to determine that the fans are installed correctly and operating efficiently. The combined control and monitor wires may be used to supply a control voltage to the fans, monitor current draw, and in some cases monitor other information such as rpm, output temperature, or output flow rate.

Position sensors 64 may further contain a physical feature that precludes the incorrect installation of outboard fan 8 and inboard fan 16, i.e. prevents an accidental installation that would cause air to flow in the wrong direction. Such an incorrect installation could cause immediate damage to the components being cooled.

The information provided by combined monitor and control wires 66 may be used by controller 40 as leading indicators of potential fan failure. As an example, a drop in rpm for a given voltage input may indicate that a bearing is failing. Controller 40 may initially respond by increasing the voltage input to that fan, and alerting the user to the problem. The controller 40 may ultimately respond by shutting down the defective fan and changing the load over to the alternative fan if the problem persists. Most importantly, the information allows the fan to make proactive responses to an impending problem before cooled component(s) 62 becomes overheated.

Controller 40 may communicate with the user through control panel 30 which contains indicator lights 32a, 32b, and 32c which may be used to indicate the status of outboard fan 8, filter element / diffuser 14, and inboard fan 16 respectively. Any commonly understood indicator algorithm may be used, for example green meaning normal

operation, yellow meaning that a component should be replaced due to sub-optimal performance or impending failure, and red or flashing red used to indicate that a component has failed. Note that a failed fan does not mean that compact dual redundant cooling fan is not operating; it simply means that the system is only running with one fan and has no ability to respond to a further fan failure. Therefore the failed component must be replaced immediately to avoid potential problems.

As an example, controller 40 may be used to monitor the amount of time that filter element / diffuser 14 is in use, and to activate the appropriate indicator light 32 should the "in use" time exceed a recommended maximum. This will alert the operator to replace filter element / diffuser 14. The appropriate position sensor 64 in may be used to automatically reset the "in use" timer back to zero

Controller 40 may also communicate with the user through a second redundant set of internal indicator lights 33 (reference FIG. 8). These lights may be more visible to the user or service technician when the fans are being replaced, and therefore they will serve as a safeguard to prevent the accidental removal of a correctly operating fan. Such a mistake would leave only the defective fan in place, potentially causing immediate damage to cooled component(s) 62. Controller 40 may use an audible emergency signal to instantly warn the user of such a dangerous situation.

FIG. 12 presents a control algorithm for the compact redundant cooling fan controller in flow chart format.

The fundamental purpose of the controller is to keep cooled component(s) 62 (reference FIG. 11) within a defined control temperature range, despite changes on workload that might affect the heat dissipated by cooled component(s) 62. Therefore the first task in each control cycle is to check for anticipated changes in workload as outlined in first decision triangle 80. This information may come from the operating system associated with cooled component(s) 62. An increase in workload would cause the controller to increase the output CFM control point, and a decrease in workload would cause the controller to decrease the output CFM control point, perhaps after some delay period, as indicated by first control box 86. The controller would proceed directly to second decision triangle 82 should there be no anticipated changes in workload.

At second decision triangle 82 the controller will check to ensure that cooled component(s) 62 (reference FIG. 11) is operating within its defined control temperature range. Should this not be the case, then the controller will adjust the output CFM control point to raise or lower the temperature of cooled component(s) 62 as required. However under normal operation, when no adjustment is required, the controller will proceed directly to third decision triangle 84.

At third decision triangle 84, the controller checks to ensure that the output CFM, i.e. combined airflow 22 (reference FIG. 11), is at the output CFM control point. Should there be a discrepancy that lies outside of the acceptable control range, then the controller will immediately investigate to determine the cause of the problem. As an example, inboard fan 16 (reference FIG. 11) may have suffered a drop in rpm given the same input parameters, a possible leading indicator of impending fan failure. The controller would then proceed to take corrective action by adjusting the inputs to inboard fan 16 and notifying the user through indicator lights 32 (reference FIG. 11).

Under normal circumstances the output of the compact redundant fan assembly will be at the required constant output CFM control point and no corrective action will be required. In this case the controller loops back to first decision triangle 80 to repeat the above control cycle once again.

While operating normally, the controller may actually change the speed of both fans slightly on a regular timed basis. These subtle changes in rpm will prevent any lasting beat frequencies that might occur if the fans are left running at a constant rpm for any length of time.

Interrupts may be used at any time to alert the controller regarding a situation that requires immediate attention. Examples may include a locked rotor ("0" rpm with a full normal input) or perhaps a dislodged fan. In these cases the controller must take immediate action to preserve a constant CFM output, thus keeping the cooled component(s) at the required operating temperature.

The present invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. Certain adaptations and modifications of the invention will be obvious to those skilled in the art. Therefore, the above-discussed embodiments are considered to be illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

We Claim:

1. A compact dual redundant cooling fan assembly comprising:

   a) An outboard cooling fan;
   b) An inboard cooling fan; mounted a distance from and in series with said outboard cooling fan;
   c) A flow modification element mounted between said outboard cooling fan and said inboard cooling fan;
   d) A connecting sleeve, said connecting sleeve directing the output of said outboard cooling fan through said flow modification element and into said inboard cooling fan; said connecting sleeve further directing the combined output of said outboard fan and said inboard fan into a cabinet containing components to be cooled;
   e) A sliding drawer configured to detachably hold said outboard cooling fan, said flow modification element, and said inboard cooling fan; said drawer further configured to slide into and out of said connecting sleeve;
   f) At least one sensor monitoring the status of each of said outboard cooling fan and said inboard cooling fan;
   g) A power source
   h) A controller in communication with said sensors, said power source, said inboard fan, and said outboard fan;

   wherein said controller is configured to maintain said combined output above a minimum control level at all times, regardless of the failure of said outboard fan or said inboard fan.

2. A compact dual redundant cooling fan assembly as claimed in claim 1 further comprising more than two fans connected in series, each separated by an appropriate said flow modification element.
3. A compact dual redundant cooling fan assembly as claimed in claim 1 wherein at least one said flow modification element is a filter.

4. A compact dual redundant cooling fan assembly as claimed in claim 1 wherein said flow modification element is comprised of a series of vanes or tubes configured coaxially with said outboard fan and said inboard fan.
5. A compact dual redundant cooling fan assembly as claimed in claim 1 wherein said flow modification element is comprised of a series of vanes or tubes configured to create a spiralling laminar flow of air over the fixed blades of defective said outboard fan or defective said inboard fan.
6. A compact dual redundant cooling fan assembly as claimed in claim 1 wherein said flow modification element is comprised of a series of tubes with an air funnel at each entry point, said air funnels opening towards and skewed towards the source of the airflow as it comes of the blades of said outboard fan.
7. A compact dual redundant cooling fan assembly as claimed in claim 1 wherein the fans blades of said outboard fan and the fan blades of said inboard fan may be configured with adjustable pitch to return to a low airflow impedance position when locked.
8. A compact dual redundant cooling fan assembly as claimed in claim 1 wherein said outboard fan and said inboard fan both normally operate at less than full rotating speed.
9. A compact dual redundant cooling fan assembly as claimed in claim 1 wherein the rotating speed of said outboard fan or said inboard fan may be increased to compensate for the failure of another fan.
10. A compact dual redundant cooling fan assembly as claimed in claim 1 wherein two such compact dual redundant cooling fan assemblies may be mounted in parallel to provide greater fault tolerant capacity.
11. A compact dual redundant cooling fan assembly as claimed in claim 1 further comprising an indicator means to alert an operator regarding a the location and status of faulty component.
12. A compact dual redundant cooling fan assembly as claimed in claim 1 further comprising a redundant indictor means to confirm the identity of the faulty component, said redundant indicator means being visible when said sliding drawer is pulled out from said cabinet.
13. A compact dual redundant cooling fan assembly as claimed in claim 1 wherein said sliding drawer may be pulled out from said cabinet in a limited and controlled fashion while the system within said cabinet is still in operation.

14. A compact dual redundant cooling fan assembly as claimed in claim 1 further comprising a physical means to prevent the accidental reverse installation of said outboard fan, said flow modification element, or said inboard fan.

15. A compact dual redundant cooling fan assembly as claimed in claim 1 wherein said outboard fan, said flow modification element, or said inboard fan may be replaced while said drawer is pulled out from said cabinet and while the system within said cabinet is still in operation.

16. A compact dual redundant cooling fan assembly as claimed in claim 1 wherein said sliding drawer may be completely removed from said connecting sleeve and said cabinet when required.

17. A compact dual redundant cooling fan assembly as claimed in claim 1 wherein said outboard fan and said inboard fan may rotate in the same or different directions.

18. A compact dual redundant cooling fan assembly as claimed in claim 1 wherein said outboard fan and said inboard fan may have the same or different capacity ratings.

19. A compact dual redundant cooling fan assembly as claimed in claim 1 wherein the direction of flow of said combined output remains consistent in the event of a failure of said outboard fan or the failure of said inboard fan.

20. A compact dual redundant cooling fan assembly as claimed in claim 1 further comprising a means to attach said connecting sleeve to said cabinet.

21. A compact dual redundant cooling fan assembly as claimed in claim 1 further comprising sensors attached to said outboard fan and said inboard fan and capable of predicting the impending failure of said outboard fan and said inboard fan.

22. A compact dual redundant cooling fan assembly as claimed in claim 1 wherein said sliding drawer may be configured to accommodate a variety of standard size fans.

23. A compact dual redundant cooling fan assembly as claimed in claim 1 further comprising shims to allow the installation of less than maximum capacity standard sized fans, said shims being installed with said outboard fan or said inboard fan to hold it securely in place; wherein said shims may be removed at any time to allow said outboard fan or said inboard to be upgraded.

24. A compact dual redundant cooling fan assembly as claimed in claim 1 wherein said controller is in communication with the operating system associated with the system contained in said cabinet, wherein said operating system may inform said controller of upcoming changes in cooling requirements.

25. A compact dual redundant cooling fan assembly as claimed in claim 1 further comprising a temperature sensor in thermal communication with the component(s) being cooled, wherein said temperature sensor is also in communication with said controller, and wherein said controller may respond to changes the temperature of said component(s).

26. A compact dual redundant cooling fan with baffles comprising:

a) An outboard cooling fan;
b) An inboard cooling fan, mounted a distance from and in series with said outboard cooling fan,
c) A flow modification element mounted between said outboard cooling fan and said inboard cooling fan;
d) An air inlet baffle configured to allow the free flow of air past said outboard cooling fan in response to a failed said outboard fan;
e) An air outlet baffle configured to allow the free flow of air past said inboard cooling fan in response to a failed said inboard cooling fan
f) A connecting sleeve, said connecting sleeve directing the output of said outboard cooling fan through said flow modification element and into said inboard cooling fan; said connecting sleeve further directing the combined output of said outboard fan and said inboard fan into a cabinet containing components to be cooled; said connecting sleeve further configured to accommodate said air inlet baffle and said air outlet baffle;
g) A sliding drawer configured to detachably hold said outboard cooling fan, said flow modification element, and said inboard cooling fan; said drawer further configured to slide into and out of said connecting sleeve; said drawer further configured to accommodate said air inlet baffle and said air outlet baffle;
h) At least one sensor monitoring the status of each of said outboard cooling fan and said inboard cooling fan;

i) A power source
j) A controller in communication with said sensors, said power source, said inboard fan, and said outboard fan;

wherein said controller is configured to maintain said combined output above a minimum control level at all times, regardless of the failure of said outboard fan or said inboard fan.

27. A compact dual redundant cooling fan with baffles as claimed in claim 26 further comprising more than two fans connected in series, each separated by an appropriate said flow modification element.
28. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein at least one said flow modification element is a filter.
29. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein said flow modification element is comprised of a series of vanes or tubes configured coaxially with said outboard fan and said inboard fan.
30. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein said flow modification element is comprised of a series of vanes or tubes configured to create a spiralling laminar flow of air over the fixed blades of defective said outboard fan or defective said inboard fan.
31. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein said flow modification element is comprised of a series of tubes with an air funnel at each entry point, said air funnels opening towards and skewed towards the source of the airflow as it comes of the blades of said outboard fan.
32. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein the fans blades of said outboard fan and the fan blades of said inboard fan may be configured with adjustable pitch to return to a low airflow impedance position when locked.
33. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein said outboard fan and said inboard fan both normally operate at less than full rotating speed.
34. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein the rotating speed of said outboard fan or said inboard fan may be increased to compensate for the failure of another fan.

35. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein two such compact dual redundant cooling fan assemblies may be mounted in parallel to provide greater fault tolerant capacity.
36. A compact dual redundant cooling fan with baffles as claimed in claim 26 further comprising an indicator means to alert an operator regarding a the location and status of faulty component.
37. A compact dual redundant cooling fan with baffles as claimed in claim 26 further comprising a redundant indictor means to confirm the identity of the faulty component, said redundant indicator means being visible when said sliding drawer is pulled out from said cabinet.
38. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein said sliding drawer may be pulled out from said cabinet in a limited and controlled fashion while the system within said cabinet is still in operation.
39. A compact dual redundant cooling fan with baffles as claimed in claim 26 further comprising a physical means to prevent the accidental reverse installation of said outboard fan, said flow modification element, or said inboard fan.
40. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein said outboard fan, said flow modification element, or said inboard fan may be replaced while said drawer is pulled out from said cabinet and while the system within said cabinet is still in operation.
41. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein said sliding drawer may be completely removed from said connecting sleeve and said cabinet when required.
42. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein said outboard fan and said inboard fan may rotate in the same or different directions.
43. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein said outboard fan and said inboard fan may have the same or different capacity ratings.
44. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein the direction of flow of said combined output remains consistent in the event of a failure of said outboard fan or the failure of said inboard fan.
45. A compact dual redundant cooling fan with baffles as claimed in claim 26 further comprising a means to attach said connecting sleeve to said cabinet.

46. A compact dual redundant cooling fan with baffles as claimed in claim 26 further comprising sensors attached to said outboard fan and said inboard fan and capable of predicting the impending failure of said outboard fan and said inboard fan.
47. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein said sliding drawer may be configured to accommodate a variety of standard size fans.
48. A compact dual redundant cooling fan with baffles as claimed in claim 26 further comprising shims to allow the installation of less than maximum capacity standard sized fans, said shims being installed with said outboard fan or said inboard fan to hold it securely in place; wherein said shims may be removed at any time to allow said outboard fan or said inboard to be upgraded.
49. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein said air inlet baffle and said air outlet baffle may be configured to automatically respond to changes in relative air pressure.
50. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein the position of said air inlet baffle and said outlet baffle may be controlled by said controller.
51. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein said outboard fan and said inboard fan are configured with an offset yet parallel axis, wherein said axis is also parallel to said combined output.
52. A compact dual redundant cooling fan with baffles as claimed in claim 26 wherein said outboard fan and said inboard fan may be configured at an angle to said parallel axis, and not necessarily in coaxial fashion.
53. A compact dual redundant cooling fan assembly with baffles as claimed in claim 26 wherein said controller is in communication with the operating system associated with the system contained in said cabinet, wherein said operating system may inform said controller of upcoming changes in cooling requirements.
54. A compact dual redundant cooling fan assembly with baffles as claimed in claim 26 further comprising a temperature sensor in thermal communication with the component(s) being cooled, wherein said temperature sensor is also in communication with said controller, and wherein said controller may respond to changes the temperature of said component(s).

Figure 1

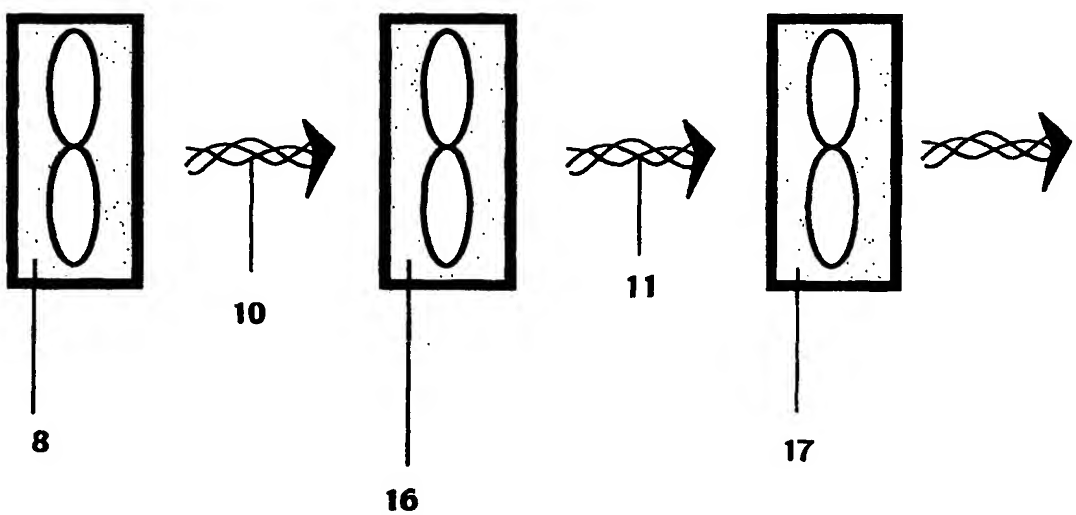


Figure 2

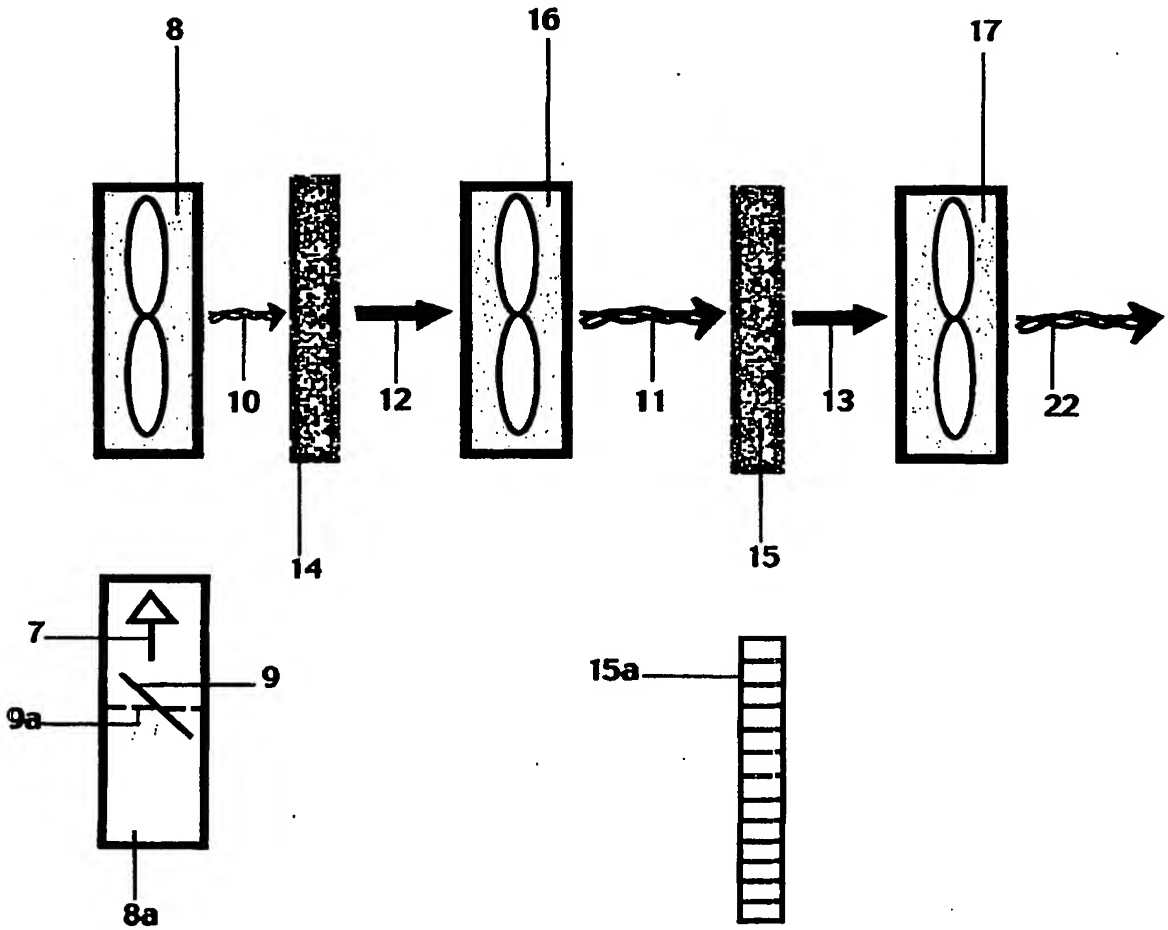


Figure 3

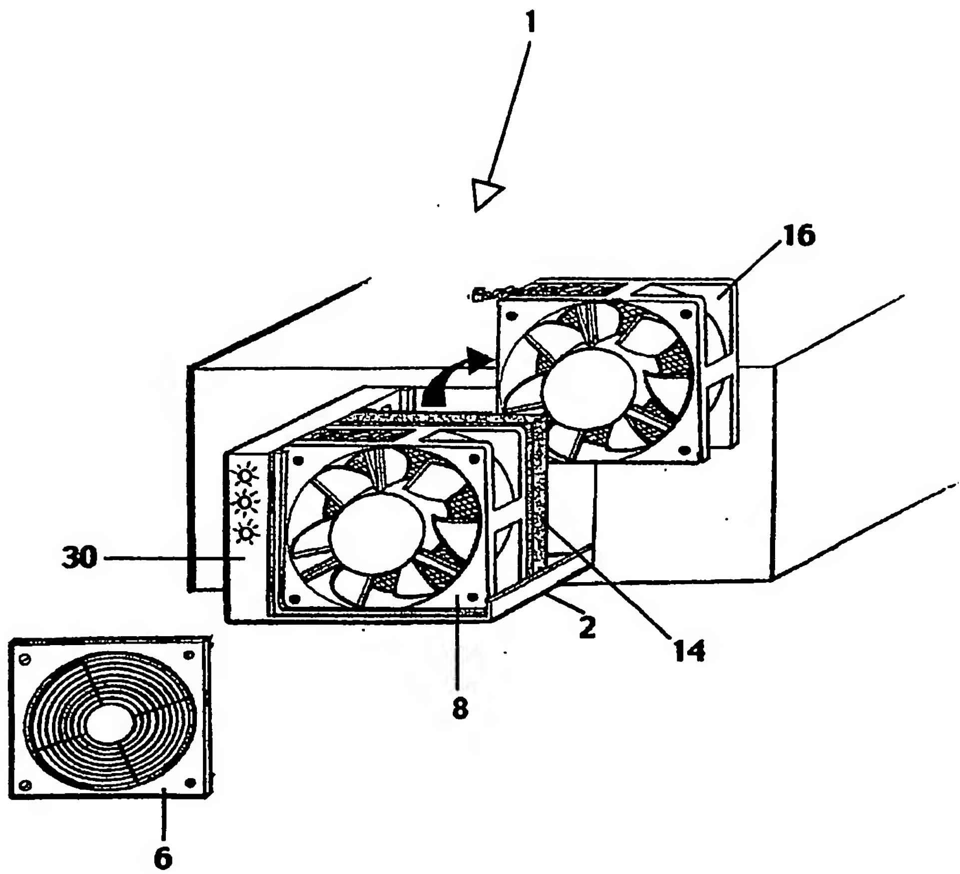


Figure 4

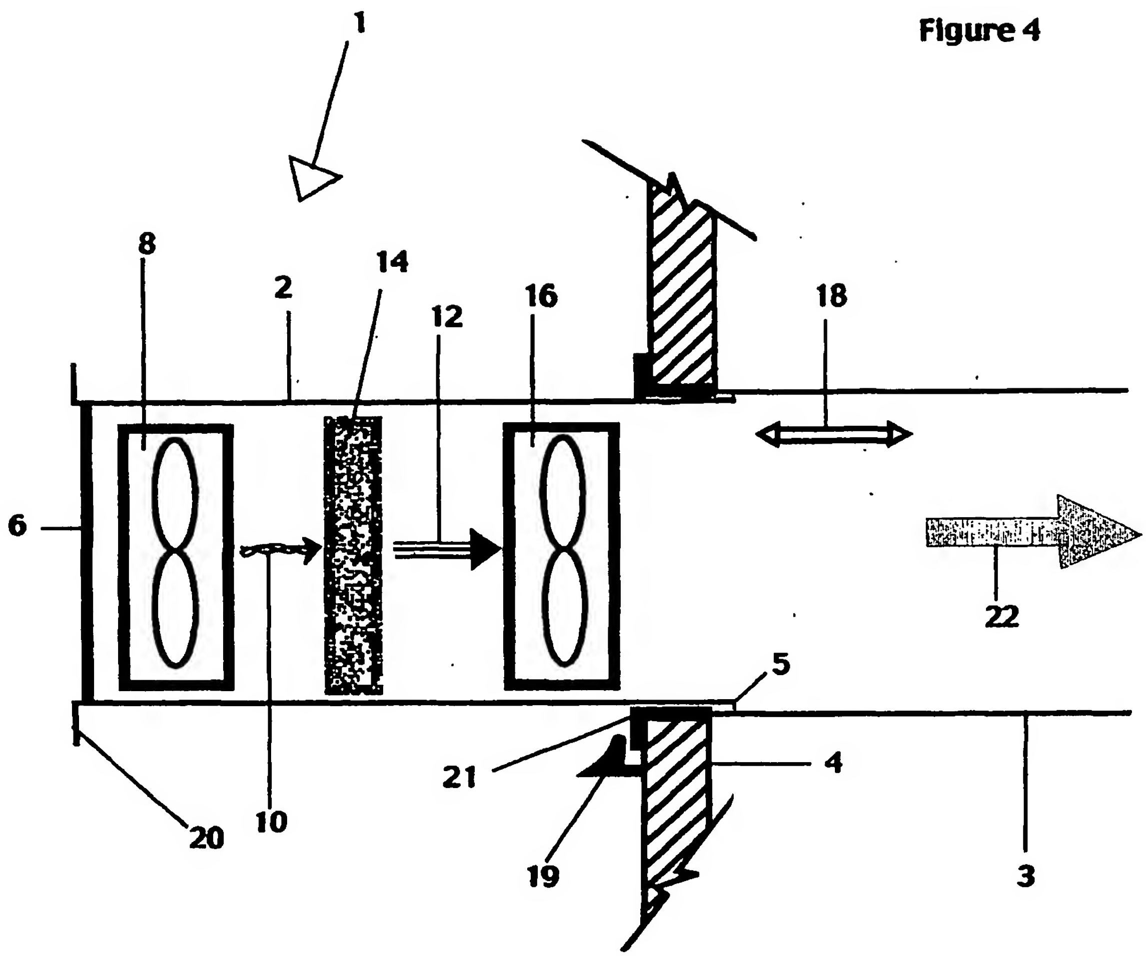


Figure 5

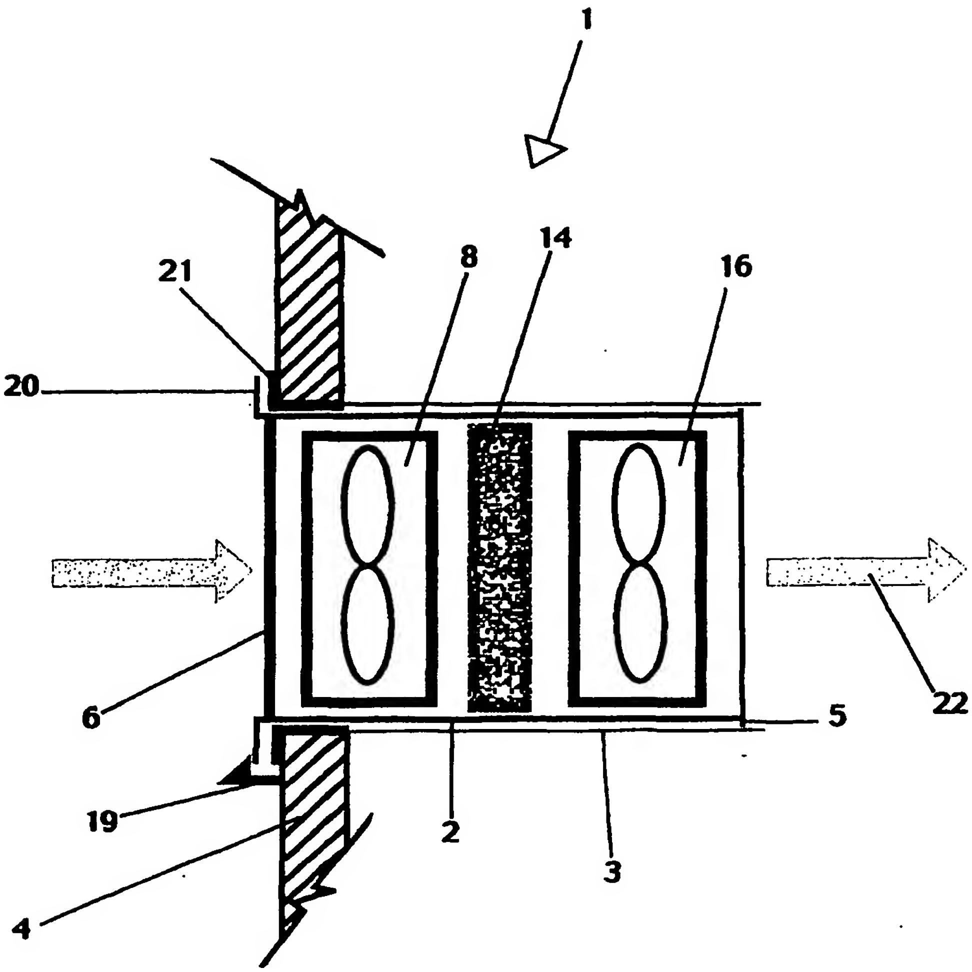


Figure 6

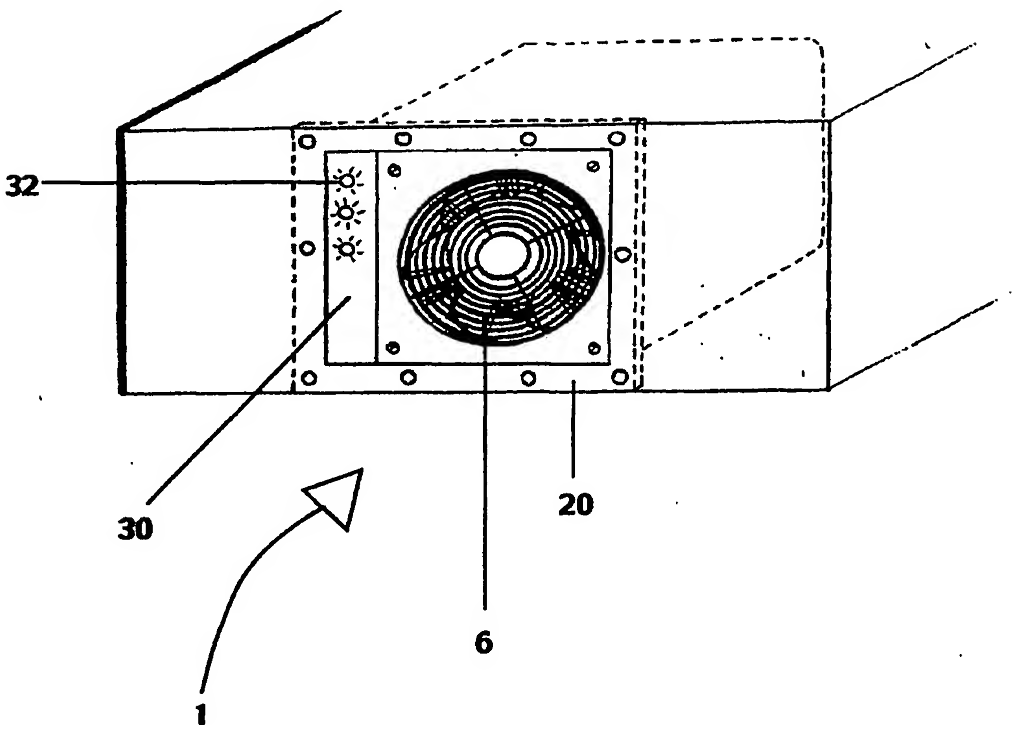


Figure 7

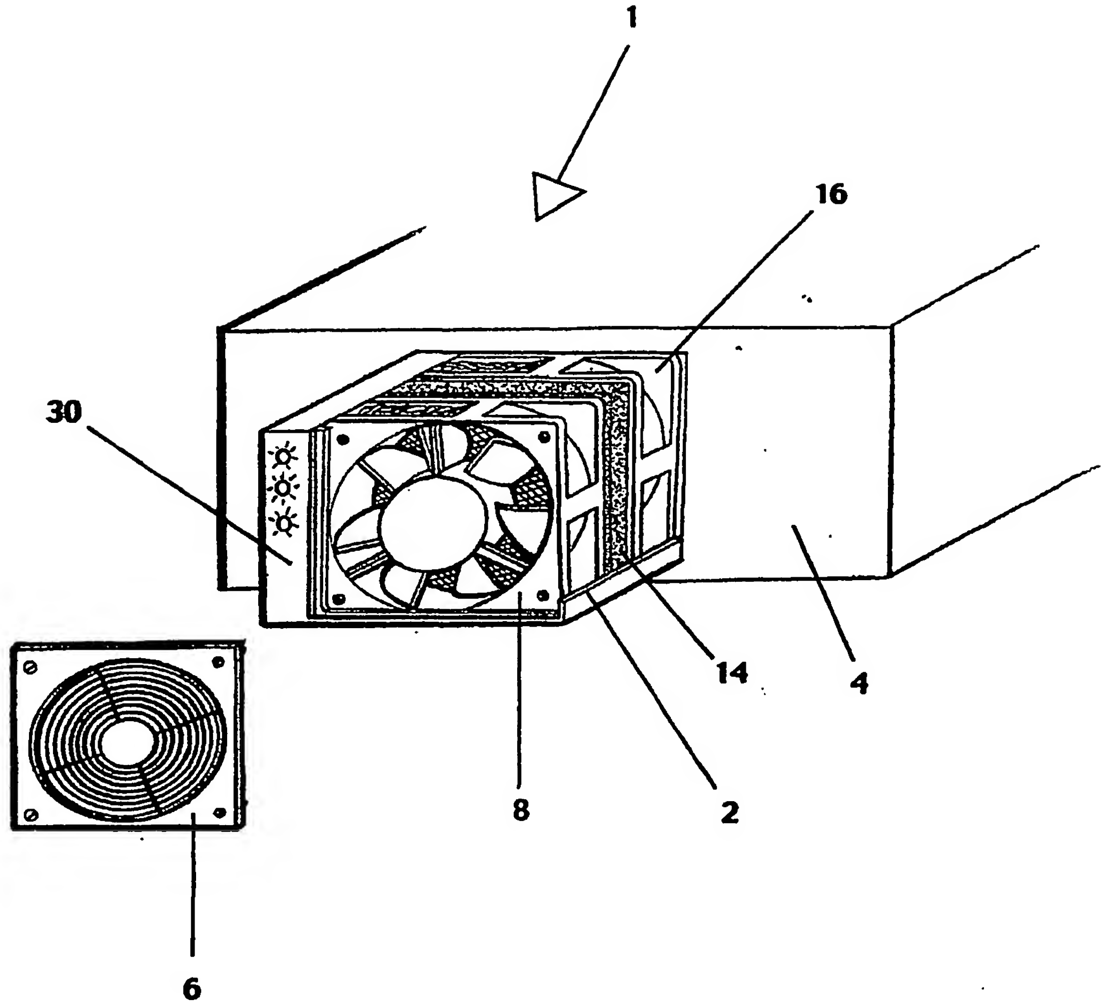


Figure 8

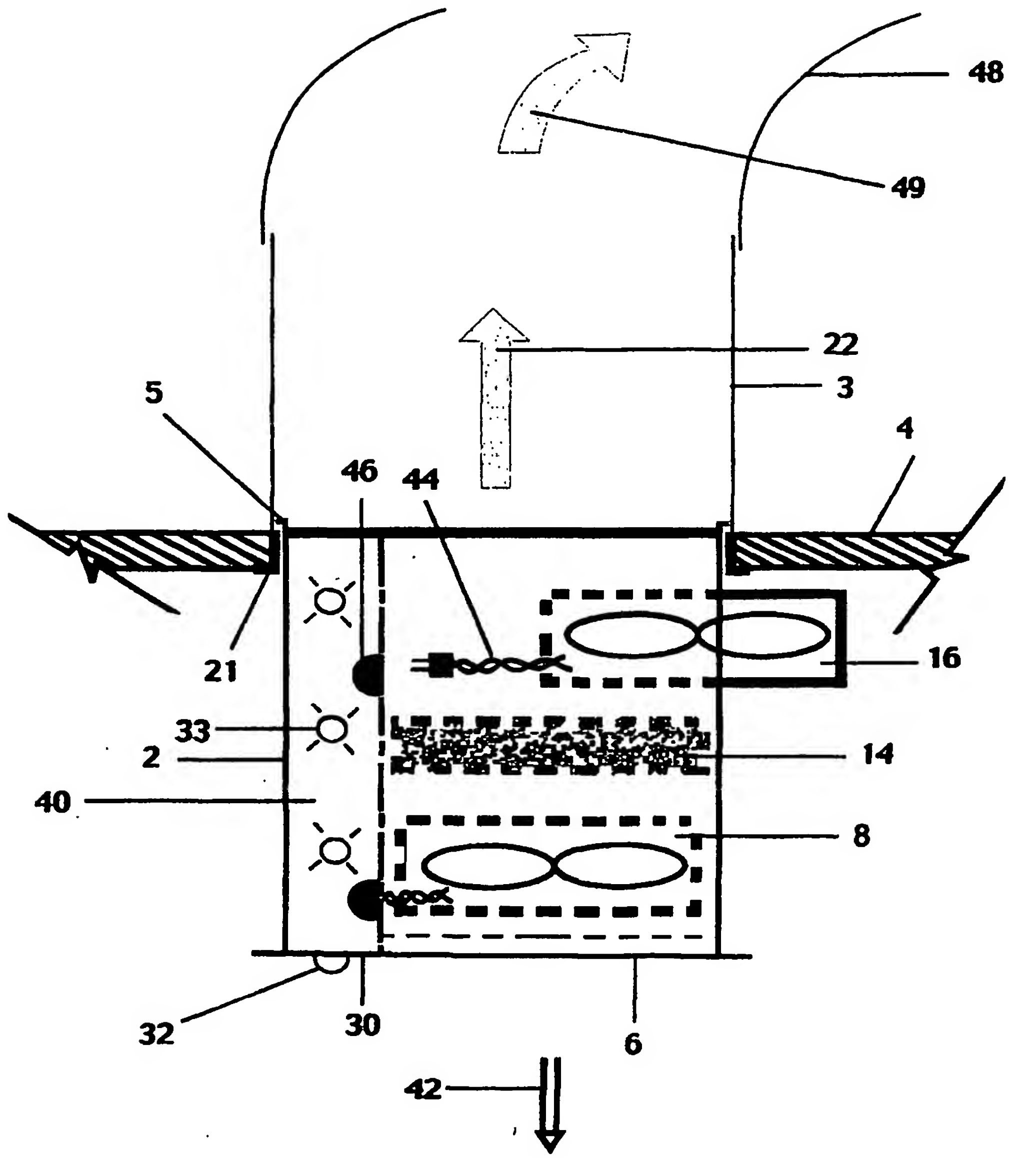


Figure 9

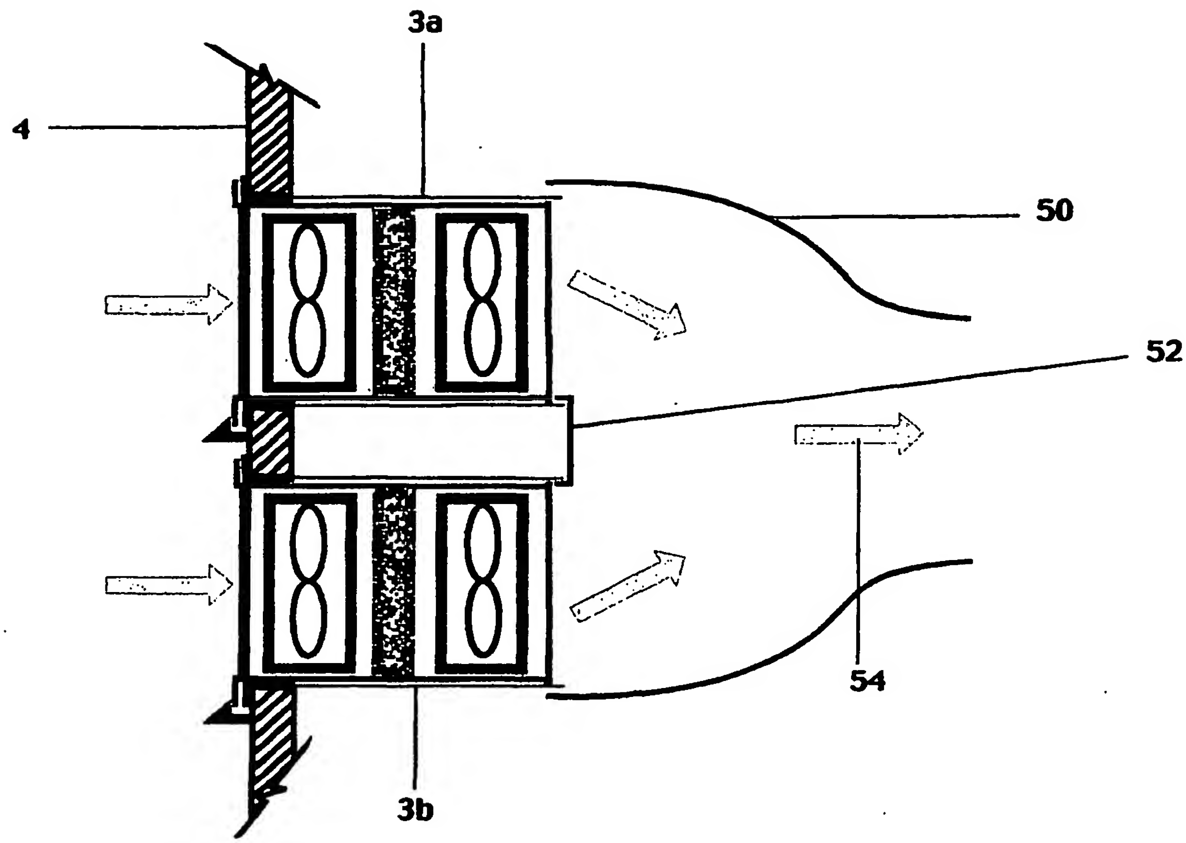


Figure 10

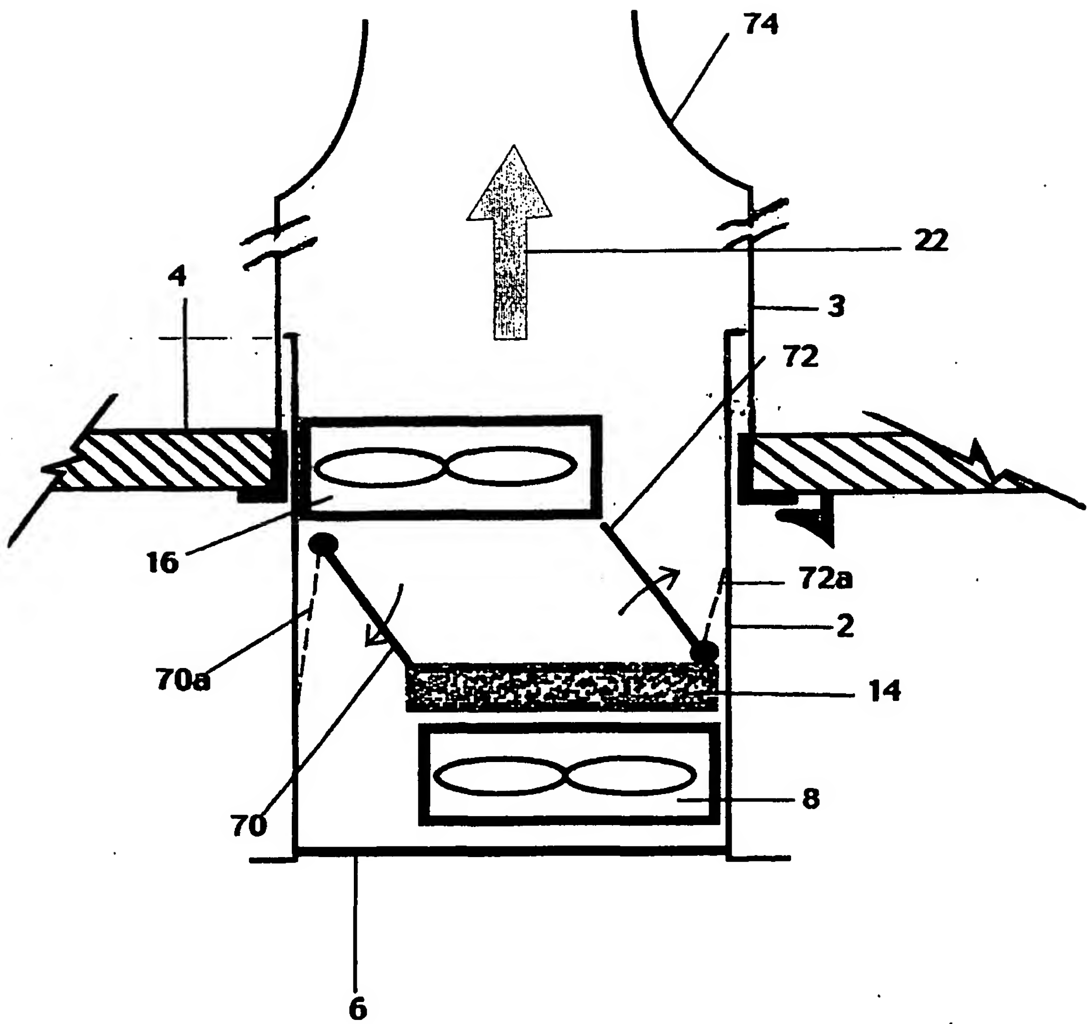


Figure 11

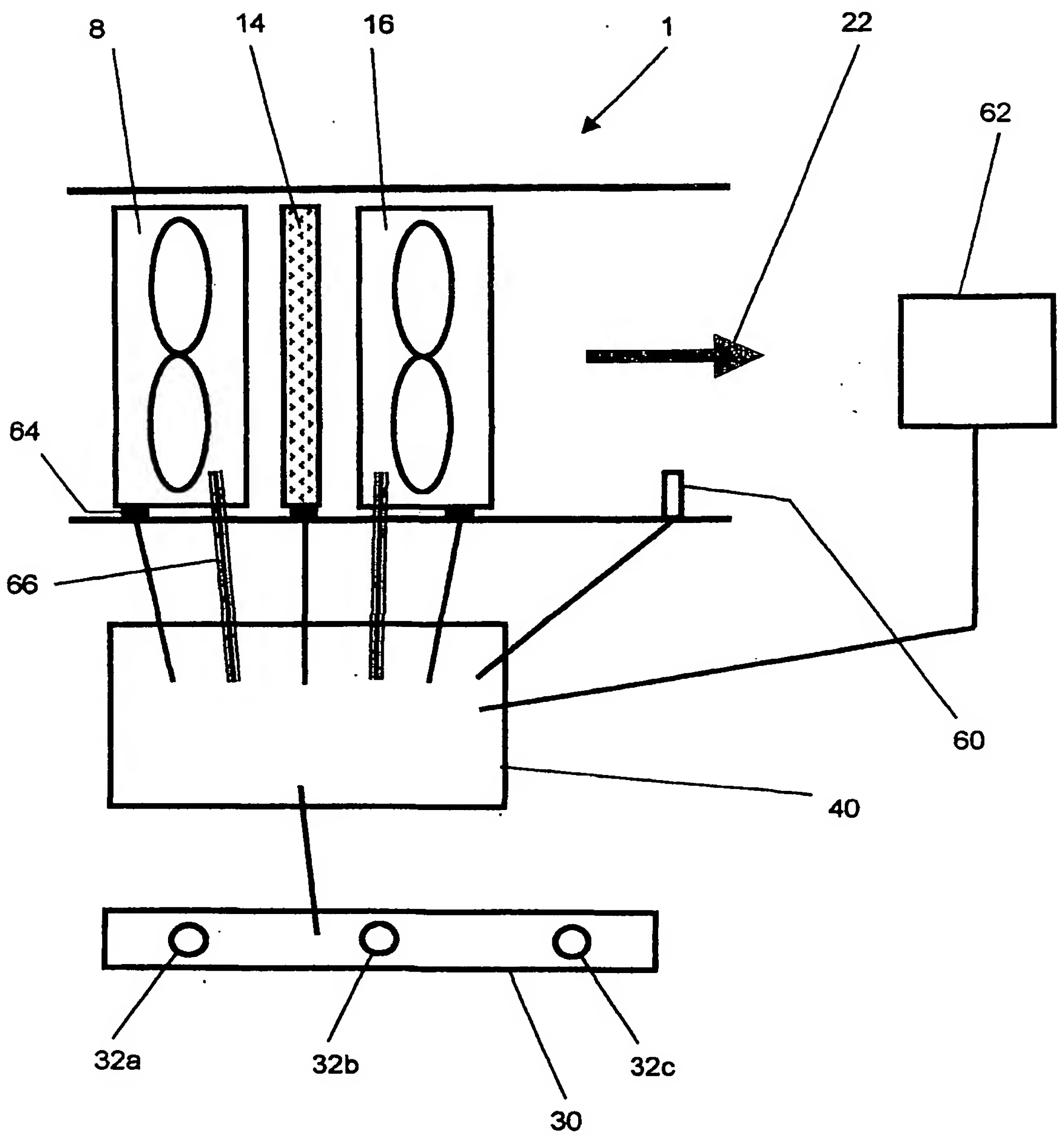
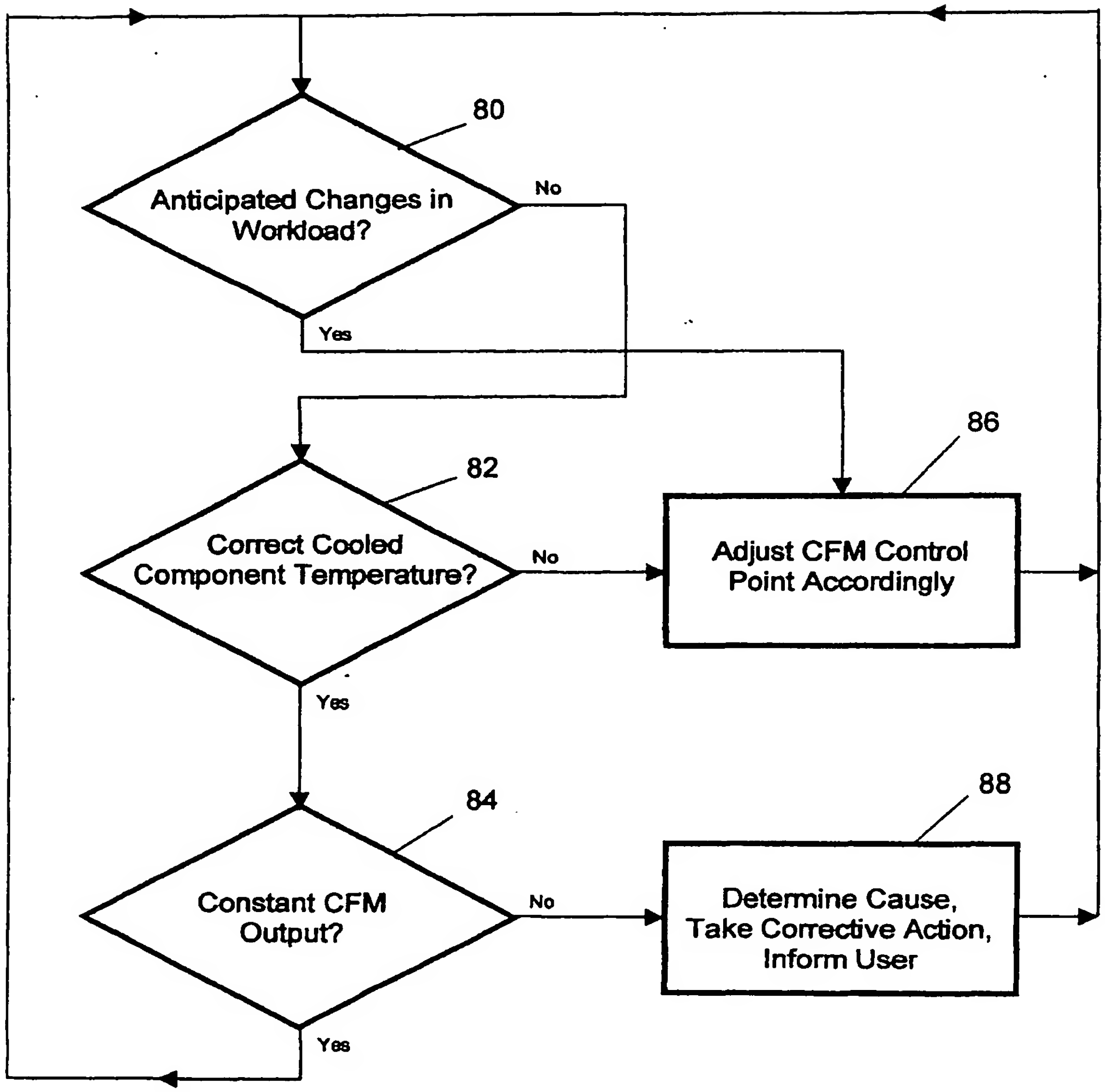


Figure 12


80
Anticipated Changes in Workload?
No
Yes
82
Correct Cooled Component Temperature?
No
Yes
84
Constant CFM Output?
No
Yes
86
Adjust CFM Control Point Accordingly
88
Determine Cause, Take Corrective Action, Inform User